DE 103 08 124.0-14

METHOD FOR DEEP-ROLLING TRANSITIONS BETWEEN THE BEARING JOURNALS AND THE FLANGES OF CRANKSHAFTS

The invention pertains to a method for deep-rolling radii or fillets at the transitions between the bearing journals and the adjacent flange of a bearing point of a crankshaft with the aid of deep-rolling cylinders that are pressed into the radius or the fillet of the transition with a deep-rolling force while the crankshaft is turned until a predetermined roll-down depth is reached.

Deep-rolling tools for deep-rolling fillets on the bearing journals of crankshafts are known, for example, from US 6,393,885 B1. Internal compressive stresses are produced in the metal of the fillets of the crankshaft with the aid of known deep-rolling methods, wherein these compressive stresses may extend, for example, to a depth of 4 mm. The actual value of the rounding radii of deep-rolling cylinders should, as is known, be determined in such a way that they lie within the manufacturing tolerances for the fillets on the crankshaft. Adequate results are achieved if the rounding radius of the deep-rolling cylinder approximately conforms to the radius of the fillet. The deep-rolling force exerted by the deep-rolling cylinders can be increased or decreased while the crankshaft is turned in order to produce patterns of concentrated internal compressive stresses in the metal of the fillets that represent the regions of a crankshaft which are subjected to the highest loads. The intensity of the deep-rolling force as well as the number of fillet rolling passes can, as is known, be predetermined in order to achieve an optimal fatigue strength. It is also advantageous to increase the actual width of the bearing journals of crankshafts. However, in order to achieve an

increase in the effective width of journals deep-rolling cylinders with smaller and compound rounding radii are utilized in order to deep-roll the fillets that, in turn, are also realized with smaller radii. The information disclosed in the U.S. patent ultimately culminates in the deep-rolling force being divided by the back-up roller and being transmitted onto lateral shoulder surfaces of the deep-rolling cylinders. The components of the deep-rolling force are then recombined by the deep rolling cylinders and transmitted by these cylinders onto the fillets such that the fillets of the bearing journals are deep-rolled and compressed. The division of the deep-rolling force with the aid of the back-up roller reduces the wear of the deep-rolling cylinders in comparison with the hitherto known state of the art.

DE 197 40 290 A1 discloses a method for deep-rolling, in particular, crankshafts. According to this method, it is not only possible to reduce the rolling forces and consequently the cylinder wear significantly, but also an optimization of the internal stresses with respect to their spatial distribution on the crankshaft and their intensity can be achieved. This method also allows the deep-rolling of high-strength materials. This known method thus makes it possible to increase the material stresses during the deep-rolling, for example, on the transition or undercut radii that are subjected to particularly high loads during operation, namely in such a way that higher internal stresses can still be achieved with reduced rolling pressures. This makes it possible, in turn, to increase the transition or undercut radii so as to reduce the notch effects occurring at these locations.

It is also known from DE 100 60 219 A1 to determine the quality of a deep-rolled crankshaft with the aid of several calipers that are respectively assigned to one of the crankshaft main bearings. Depending on the result of the measurement, in addition to a first deep-rolling operation a further deep-rolling operation may be carried out in order to reroll the radii or fillets of individual bearing points purposefully. The entire circumference of the bearing point in question or only a part thereof may be subjected to the rerolling process. The radii or fillets on individual main bearings or on the journals of the crankshaft may be included in the rerolling process.

In comparison with the state of the art, it was determined that the deep-rolling of such transitions produces internal compressive stresses in the radii or fillets of the crankshafts, wherein the maximum of these internal compressive stresses lies at a depth between 0.6 and 1.2 mm below the deep-rolled surface. The highest stress occurs in the transition due to the operating strain of the crankshaft in the form of rotating bending. The bending stresses of the operation are superimposed with the internal compressive stresses resulting from the deep-rolling and the yielding point is exceeded. The internal compressive stresses then weaken.

Incipient cracks can be observed on the surface of the deep-rolled transition, wherein these cracks extend up to the depth at which the highest internal compressive stresses below the surface were produced.

The invention is thus based on the objective of improving the fatigue strength of crankshafts by means of deep-rolling in such a way that the operation of the

crankshaft no longer causes any incipient cracks to occur on the deep-rolled surface of the transitions.

According to the invention, this objective is attained by deep-rolling the transition between the bearing journals and the adjacent flange of a bearing point of a crankshaft, wherein the transition

- is initially deep-rolled with a first deep-rolling cylinder, the radius of which has an osculating ratio between 1 and 0.85 referred to the radius of the transition or the fillet, namely with a first deep-rolling force that produces a maximum internal compressive stress in the transition at a depth between 1 and 2 mm below the deep-rolled surface, and
- the same transition is subsequently rerolled with a second deep-rolling cylinder that has a smaller radius than the first deep-rolling cylinder, namely with a second deep-rolling force of such magnitude that the second deep-rolling cylinder causes a further plastic deformation on the deep-rolled surface of the transition in addition to the plastic deformation achieved with the first deep-rolling cylinder.

The second rolling process shifts the maximum of the internal compressive stresses produced during the initial rolling process closer to the surface. This results in a new pattern of internal compressive stresses which lies closer to the deep-rolled surface and consequently prevents the formation of incipient cracks.

The rerolling of the surfaces may be realized, for example, with a second deep-rolling tool in a second

deep-rolling operation. However, it would also be conceivable to construct deep-rolling tools in such a way that several deep-rolling cylinders with different rounding radii are combined and successively engaged.

It is advantageous if the roll-down depth achieved with the first deep-rolling cylinder is approximately 0.2 mm and the additional roll-down depth achieved with the second deep-rolling cylinder is approximately 0.05 mm; this means that the total roll-down depth amounts to 0.25 mm.

One embodiment of the invention is described in greater detail below.

The figure shows an enlarged detail of the transition at the bearing point of a crankshaft.

The crankshaft 1 has a bearing journal 3 and a flange 4 that transform into one another via a fillet 2. The fillet 2 has a radius 6. The fillet 2 has the contour indicated with the broken line 15 prior to the deep-rolling process.

The surface indicated with the line 8 is obtained after the deep-rolling process with a (not-shown) first deep-rolling cylinder that has the radius 5. For example, the normal 12 referred to the surface 8 reaches a first roll-down depth 10. The roll-down depth 10 corresponds to an internal compressive stress 16 within the material of the crankshaft 1 which has its maximum 7 far below the deep-rolled surface 8 as shown in the figure.

According to the invention, the deep-rolled surface 8 is rerolled with a (not-shown) second deep-rolling cylinder

that has a radius 14. This causes an additional plastic deformation in the fillet 2 which is indicated with the line 9. An additional roll-down depth 11 is reached underneath the initial roll-down depth 10 in the direction of the normal 12. The first roll-down depth 10 is approximately 0.2 mm, and the additional roll-down depth 11 is approximately 0.05 mm. This simultaneously causes a near-surface internal compressive stress 13 to be induced in the transition 2 of the crankshaft material, wherein this internal compressive stress prevents incipient cracks from forming on the surface 9 in the direction of the normal 12 during the operation of the crankshaft 12. The fatigue strength of the crankshaft 1 can be effectively increased in this fashion.

LIST OF REFERENCE SYMBOLS

1	Crankshaft
2	Fillet
3	Bearing journal
4	Flange
5	Roll-down depth
6	Radius of the fillet
7	Maximum of the internal compressive stress
8	Deep-rolled surface
9	Additional plastic deformation
10	First roll-down depth
11	Second roll-down depth
12	Normal
13	Near surface internal compressive stress
14	Smaller radius
15	Contour
16	Internal compressive stress